observation. The value calculated from $(1 - \mu^{-2})$ would be 0036."

We have seen that, so far as the first power of v/V is concerned, Fresnel's theory agrees with all the facts of the case. The question whether it is possible to contrive an experiment in which v^2/V^2 shall be sensible, has been considered by Michelson,[1] who, having arrived at an affirmative conclusion, proceeded to attack this very difficult experimental problem. In Michelson's apparatus interference is brought about between two rays, coming of course originally from the same source, one of which has traversed to and fro a distance, D, parallel to the earth's motion, and the other a like distance in the perpendicular direction. The phase of the latter ray is considered by Michelson to be unaffected by the earth's motion. As to the former, it is retarded by the amount

$$\frac{D}{V - v} + \frac{D}{V + v} - \frac{2D}{V} = \frac{2D}{V} \cdot \frac{v^2}{V^2},$$

or, reckoned in distance at velocity V,

$$2D\, v^2/V^2. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

"Considering only the velocity of the earth in its orbit, the ratio $v/V = 10^{-4}$ approximately, and $v^2/V^2 = 10^{-8}$. If $D = 1200$ mm., or, in wave-lengths of yellow light, 2,000,000, then in terms of the same unit, $2D\, v^2/V^2 = {\cdot}04$.

"If, therefore, an apparatus is so constructed as to permit two pencils of light, which have travelled over paths at right angles to each other to interfere, the pencil which has travelled in the direction of the earth's motion, will in reality travel ·04 of a wave-length further than it would have done were the earth at rest. The other pencil, being at right angles to the motion, would not be affected.

"If now the apparatus be revolved through 90°, so that the second pencil is brought into the direction of the earth's motion, its path will be lengthened ·04 wave-length. The total change in the position of the interference bands would be ·08 of the distance between the bands, a quantity easily measurable."

In the actual experiment, the earth's velocity was not available to the full extent, and the displacement to be expected on this account was reduced to ·048; but Michelson considers that some addition to it should be made on account of the motion of the solar system as a whole. The displacement actually found was ·022; and when the apparatus was employed in such azimuths that the rotation should have had no effect in any case, ·034. These results are very small, and Michelson gives reasons for regarding them as partially systematic errors of experiment. He concludes that there is no real displacement of the bands, and that the hypothesis of a stationary æther is thus shown to be inconsistent with fact.

It has, however, been recently pointed out by Lorentz[2] that Michelson has over-estimated the effect to be expected according to Fresnel's views. The ray which travels perpendicularly to the earth's motion is not unaffected thereby, but is retarded to the amount represented by $D\, v^2/V^2$. The outstanding relative retardation is thus only $D\, v^2/V^2$, instead of the double of that quantity. Accepting this correction, we have to expect, according to Fresnel's views, a shift of only ·024 of a band in Michelson's experiment.

Under these circumstances Michelson's results can hardly be regarded as weighing heavily in the scale. It is much to be wished that the experiment should be repeated with such improvements as experience suggests. In observations spread over a year, the effects, if any, due to the earth's motion in its orbit, and to that of the solar system through space, would be separated.

On the whole, Fresnel's hypothesis of a stationary æther appears to be at the present time the more probable; but the question must be considered to be an open one. Further evidence would be most important; but it is difficult to see from what quarter anything essentially new can be expected. It might be worth while for astronomers to inquire whether it is really true, as is generally assumed, that stellar aberration is independent of the position upon the earth's surface from which the observation is made. Another question that might, perhaps, be submitted with advantage to an experimental examination is whether the propagation of light in air is affected by the rapid motion of heavy masses parallel to, and in the immediate neighbourhood of, the ray.

If we once admit the principle that, whatever the explanation may be, no ordinary[1] terrestrial observation is affected by the earth's motion, it is easy to give an account of what must happen when the light comes from an external source which may have a motion in the line of sight. Imagine, for example, a spectroscopic examination of a soda flame situated on a star and vibrating in identical periods with those of terrestrial soda flames. In accordance with Döppler's principle, the wave-lengths are altered by a relative motion in the line of sight, and the fact may be rendered evident by a comparison between the spectra of the star and of the terrestrial flame, held so as to be seen in the same direction. The simplest case is when the flame is entirely external to the apparatus, so that both lights are treated in precisely the same way. It is evident that, under these circumstances, the difference between the two cannot fail to become apparent; and this way of regarding the matter shows also that the apparent displacement of the bright lines in the stellar spectrum is dependent upon the relative, and not further upon the absolute, motions of the star and of the earth. The mean of observations, equally distributed over the year, would thus give data for determining the relative motion in the line of sight of the star and of the solar system.

If the external source be the sun itself, it might be thought that the spectra must agree almost perfectly, the eccentricity of the earth's orbit being so very small. But the sun is a revolving body, and consequently a distinction must be made according to the part of the sun from which the light proceeds. It is found, in fact, that a very sensible shift takes place in the position of the dark lines according as the light under observation comes from the advancing or from the retreating limb. This circumstance has been successfully employed by Thollon and Cornu to distinguish between lines having a solar and a terrestrial origin. In the latter case it is a matter of indifference from which part of the sun the light proceeds.

In general optical theory the finiteness of the velocity of light is usually disregarded. Velocities at least ten times greater than that of the earth in its orbit are, however, known to astronomers; and such must begin to exercise a sensible influence upon radiation. Moreover, in so wide a generalization as the theory of exchanges, the neglect of even a small quantity is unsatisfactory. Prof.[2] Balfour Stewart has discussed the influence of the motion of a plate exercising selective absorption upon the equilibrium of radiation within an inclosure. He argues that a disturbance will ensue, involving a violation of the second law of thermodynamics, unless compensated by some other effect not hitherto recognized. It appears, however, more probable that the whole radiation coming *from* and *through* a plate would not be altered by its motion. Whatever effect (in accordance with Döppler's law) the motion has upon the radiation from the plate, a similar effect would probably be produced upon the absorbing power. On this view the only result of the motion would be to change the wave-length of the rays most powerfully emitted and absorbed, but without disturbing the balance required by the theory of exchanges. The moving plate would in fact be equivalent to a stationary one of slightly different quality.

RAYLEIGH.

1887.

SOCIETIES AND ACADEMIES.

LONDON.

Mathematical Society, March 10.—Prof. Greenhill, F.R.S., President, in the chair.—The President and Mr. S. Roberts, F.R.S., spoke upon the loss the Society had sustained by the recent decease of Dr. Hirst, F.R.S., touching more especially upon the great services he had rendered to it in the early days of its existence.—The following paper was read:—The simplest equivalent of a given optical path, and the observations required to determine it, by Dr. J. Larmor. To specify an optical path through a heterogeneous medium like the atmosphere, or through an arrangement of refracting substances like an optical instrument, we require the geometrical curve followed by the filament of light, and also the character of the modification produced on a filament following this path across the medium.

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[1] *American Journal*, xxii. p. 120 (1881).

[2] "Over den invloed dien de beweging der aarde of de licht verschijnselen uitoefent." (Amsterdam, 1886.)

[1] This qualification is inserted in order to exclude such an experiment as that of Michelson, just described, in which an attempt is made to render sensible an effect depending on v^2/V^2.

[2] B.A. Report, 1871.

This division into filaments of waves, along whose course the energy of the radiation is propagated, is the true objective analysis of the light; and it also, on Sir W. R. Hamilton's principles, leads to more compact and comprehensive treatment than the ordinary analysis into linear rays. It is shown that the effect of the medium on any filament following the given path is exactly equivalent to that of a certain pair of thin astigmatic lenses with a common axis, on a beam passing across them; and a method is given for constructing these lenses from observations made at the two extremities of the actual optical path. It is shown, in continuation, that conjugate pairs of focal lines at the two ends of a filament are given by a 2 to 2 correspondence, whose general relations are exhibited graphically by the aid of a pair of conics, and various developments are made in this direction. There are, in general, no points which have conjugate foci; but, if a certain condition hold, there exist two transverse planes of points which have conjugate planes of focal points. This occurs only when the equivalent astigmatic pair of lenses have their principal sections parallel, so that the component refractions in these principal sections are independent of each other. It is only in this special case that the emergent filament can be constructed by means of rays, in Moebius's manner, by aid of the two conjugate pairs of focal planes. If a certain other condition is also satisfied, there is complete symmetry round the axis, except as regards a possible constant rotation of the filament; and then the optical path is equivalent to refraction by a single ordinary thin lens.—The President communicated a paper, by Prof. W. Burnside, on cases in which a hyper-elliptic integral of the first order can be expressed as the sum of two elliptic integrals.—Mr. Tucker read abstracts of the following notes:—On the analytical theory of the congruency, by Prof. Cayley, F.R.S.—On certain curves of the fourth order, and the porism of the inscribed and circumscribed polygon, by Mr. R. A. Roberts.—Notes on dualistic differential transformations, by Mr. E. B. Elliott, F.R.S. A perusal some time ago of De Morgan's paper in the Cambridge Transactions on the subject of the principle of duality in differential equations which bears his name led Mr. Elliott to notice a short note thereto, in which the author announced that after writing his paper he had found a note by Chasles, in which the method had been anticipated. Upon this, referring to Chasles's work ("Aperçu Historique," note xxx), he found that Chasles had stated and to a certain extent developed a theory on the subject of much wider generality. It occurred to Mr. Elliott that some further consideration might with advantage be given to Chasles's conclusions and their extension; and a portion of this paper is the result. It had previously occurred to the author that recent theories as to the transformation of differential expressions by interchange of dependent and independent variables, and in particular the theory of reciprocants, had a bearing on the more restricted or De Morgan duality, and even more on its simpler analogue as to ordinary differential equations, which had probably escaped notice. Another portion of these notes is devoted to the elucidation of this idea.—Prof. M. Hill made a few remarks on singular solutions; and the President spoke on the rectification of the Cartesian oval. It has been shown by Prof. Genocchi, of Turin (*Annali di Matematica*, 1864), and by Mr. Samuel Roberts (Proc. L.M.S. iii.), that the arc of a Cartesian oval can be expressed as the sum of three elliptic arcs. Taking a fixed oval (i.) and its conjugate oval (ii.) in a triconfocal system of Cartesians, then as a variable orthogonal oval traces out by its intersection with (i.) a certain arc, its conjugate oval traces out on (ii.) another arc; the sum of these arcs can be expressed by a single elliptic arc, while the difference is expressible as the sum of two elliptic arcs; thus leading to the theorems of Prof. Genocchi and Mr. S. Roberts.

Anthropological Institute, March 8.—Edward B. Tylor, F.R.S., President, in the chair.—Mr. J. Allen Brown read a paper on the continuity of the Palæolithic and Neolithic periods. The deductions of the author are based on the large number of flint implements of Palæolithic type which have been discovered during recent years at Eastbourne, East Dean, Cuckmere, and in other combes and dry valleys in England; at East Dean, &c., they are associated with compact aggregated deposits of flints and chalk rubble, evidently due to the erosion of the valleys and combes by underground water, as seen at Birling Gap, near Eastbourne. The valleys of Sussex have been subject to many changes during the concluding episodes (both glacial and subaërial) of the Quaternary period, and in many cases the older forms of flint implements have been covered up and preserved by the deposit of loam and chalk rubble resulting from the waste of the surface of the land. Intermixed or associated with the flint implements of older types are others of transition form, to which he desired to see the term "Mesolithic" applied. The East Dean Valley appeared to contain flint implements forming a series ranging from the late Palæolithic age to the polished stone period of true Neolithic. The old mining-shaft at Cissbury has furnished analogous specimens. Similar implements of the Palæolithic type have been found in chalk rubble far away from the sea-board, and associated with the bones of the mammoth, tichorine rhinoceros, hippopotamus, and other Quaternary Mammalia, as well as the remains of various animals of species still living, showing that man was present in Southern Britain not only in the plateaux and river-drift periods, but also continuously into the so-called Neolithic epoch. The author alluded to the evidence derived from caves and rock-shelters and peat-beds, both in this country and in France, which pointed in the same direction. A large series of flint implements of Palæolithic form from East Dean, &c., were exhibited, with specimens of corresponding forms from the river-drift; also a series showing the evolution of the axe or celt form from the simply chipped nodule of the plateaux drift, through the valley drift and transitional types to the highly finished celts of the Neolithic age, of which the forms were continued in the earliest stages of the age of copper and bronze. Other series were exhibited, showing in like manner the evolution of the spear-head and knife, &c.

Zoological Society, March 1.—Dr. A. Günther, F.R.S., Vice-President, in the chair.—The Secretary read a report on the additions that had been made to the Society's Menagerie during the month of February 1892, and called attention to two Short-winged Tyrants (*Machetornis rixosa*) purchased February 15, being the first examples of this bird that have reached the Society, and to a female Beatrix Antelope (*Oryx beatrix*) from Arabia, presented by Lieut.-Colonel Talbot, February 18.—Mr. J. Graham Kerr gave a short account of the expedition up the Rio Pilcomayo in 1890–91, which he had accompanied as naturalist. Mr. Kerr made remarks on the animals met with on the banks of the Pilcomayo, and exhibited a series of photographs illustrating the vegetation of the district and its native Indian inhabitants.—Mr. G. F. Hampson read a paper on stridulation in certain Lepidoptera, and on the distortion of the hind-wings in the males of certain *Ommatophorinæ*. The author attributed the clicking sound described by Darwin as produced by various species of the South American genus of Butterflies, *Angerona*, and confirmed by Wallace and other observers, to the presence of a pair of strong corneous hooks on the thorax, which play on a pair of curved hooks with spatulate ends attached to the inner margin of the fore-wing close to the base, and surrounded by a membranous sac which acts as a sounding-board. An account was given of a similar sound produced by the males of a Burmese moth of the family Agaristidæ and of a buzzing sound in an allied Australian form, both of which have a patch of ribbed hyaline membrane below the costa of the fore-wing. The sound was attributed to the friction of spines, attached in the former to the first pair of legs, in the latter to the second pair, on the ribbed membrane. A description was then given of the transformation of the costal half of the hind-wing in the Noctuid genus *Patula* into a large scent-gland, and of the manner in which this had distorted the neuration. The still greater distortion of the neuration in the allied genus *Argida* was attributed to its once having possessed a similar scent-gland, now become rudimentary by disuse.—A communication was read from Prof. W. N. Parker, on the retention of functional gills in young Frogs (*Rana temporaria*), which he had succeeded in producing in specimens reared in his laboratory. Prof. Parker described the method employed with this object, and made remarks on the way in which the fore-limbs are protruded.—Prof. F. Jeffrey Bell read a paper entitled "A Contribution to the Classification of Ophiuroids," to which were added descriptions of some new and little-known forms of this group.—Mr. M. F. Woodward gave an account of an abnormal Earthworm (*Lumbricus terrestris*) possessing seven pairs of ovaries situated on the eighth and following somites to the fourteenth.

OXFORD.

University Junior Scientific Club, March 4.—Mr. J. A. Gardner, of Magdalen College, President, in the chair.—Some investigations of the action of dry hydrochloric acid gas on dry carbonates were brought forward by Mr. F. R. L. Wilson, Keble College, and Mr. R. E. Hughes, Jesus College. The authors showed that probably perfectly dry hydrochloric acid gas does not act on carbonates. Experiments were tried with the carbonates of calcium and barium.—Mr. J. L. Hatton, Hertford College, read a paper on some investigations, which he had been engaged upon, in conjunction with Mr. James Walker, on the motions of the nodal planes in a rotating bell. This work appeared in a recent number of the *Philosophical Magazine*.—This paper was followed by an account of the fixation of nitrogen by plants, by Mr. O. V. Darbishire, of Balliol College.

PARIS.

Academy of Sciences, March 14.—M. d'Abbadie in the chair.—The Secretary commented upon the loss sustained by the Academy by the death of M. Léon Lalanne.—On conical vascular branches, and on the inductions to which they lead with regard to the organization of the vascular blood system, by M. Ranvier.—Researches on samarium, by M. Lecoq de Boisbaudran. By passing an electric spark from a large induction coil, without condensers, through solutions rich in samarium, and viewing the spark spectroscopically, lines were obtained at the wave-lengths 466·2, 462·7, and 459·3, and a wide band having a well-defined edge at λ 611·2, and fading away to about λ 622. The samarium bands undergo very marked variations when the position of the spark with respect to the meniscus of liquid is altered. This fact is thought to be of interest from the point of view of the supposed complexity of samarium. It is not impossible that there is a relation between the band 611–622 and the narrow line which Prof. Crookes observed when using mixtures of samarium and yttrium *in vacuo*, and which he attributed to the presence of a new element. M. Boisbaudran has observed this line, or one very near it, with different substances, and finds that its position varies sensibly with the nature of the solution employed. The narrow line is accompanied with a less refrangible and weaker one. With lanthanum sulphate mixed with a compound of samarium, the wave-length of the stronger line was determined as 612·7, and of the weaker 619·6. Prof. Crookes obtained the wave-length 609.—On a remarkable prominence, by M. H. Deslandres. The prominence was observed on the east limb of the sun on March 3, as the large spot-group of February was coming round it.—On frictionless gearings, by M. A. Rateau.—On periodic heat maxima observed in spectra furnished by flint and crown glass, and rock-salt, by M. Aymonnet. The heat maxima observed are separated by equal wave-lengths in the case of each of the prisms used, and, for rock-salt, the maxima appear to correspond to the fundamental vibrations of 1, 2, 3 . . . *n* systems of cubical molecules.—On some well-defined alloys of sodium, by M. Joannis. By the action of lead, in excess, upon sodammonium, a compound having the formula $Pb_4Na,2NH_3$ was obtained. An alloy of lead and potassium, Pb_2K, was obtained by the action of potassammonium, in excess, upon lead; an alloy of bismuth and sodium, $BiNa_3$, by treating pure bismuth, in excess, with sodammonium, and an alloy of antimony and sodium, $SbNa_3$, have similarly been produced.—On the analysis of minerals containing antimony, by M. Ad. Carnot.—On the microscopic structure of oolitic iron from Lorraine, by M. Bleicher. From the investigation it appears that the ferruginous oolites which have been studied consist of a central mineral or organic nucleus, single or multiple, surrounded by regular concentric layers of a substance rich in silica and organic matter.—On the vegetation of the vine, by MM. L. Roos and E. Thomas. Conclusions are given respecting the amounts of sugars present and the acidity of various parts of the vine plant at different stages of its growth.—Citric acid, by M. G. Massol. The heat of formation, in the solid state, of potassium and sodium citrates is greater than that of the corresponding carbally lates. The augmentation is analogous to that observed when comparing malonic and succinic acids with tartronic, tartaric, and malic acids, and is to be attributed to the alcoholic hydroxyl group.—On some reactions of the isomeric amido-benzoic acids, by M. Oechsner de Coninck.—Calculation of the temperatures of ebullition of compounds derived from the paraffins by terminal substitution, by M. G. Hinrichs.—On the pyrogenous hydrocarbons formed in the compressed gas industry, by M. A. Brochet. The author has isolated and identified the following:—

$$CH_2 : CH \,.\, CH_2 \,.\, CH_3 ;$$
$$CH_2 : CH \,.\, CH_2 \;\; CH_2 \,.\, CH_3 ;$$
$$CH_3 \,.\, CH : CH \,.\, CH_2 \,.\, CH_3 ;$$
$$CH_2 : CH \,.\, CH_2 \,.\, CH_2 \,.\, CH_2 \,.\, CH_3 ;$$
$$CH_2 : CH \,.\, CH : CH_2 ;$$
$$CH_2 : CH \,.\, CH_2 \,.\, CH : CH_2 .$$

—The specific gravity of silk, by M. Léo Vignon.—Glycolysis in the blood, by M. Maurice Arthus.—Are there inhibitory nerves?, by M. J. P. Morat.—On an anomaly in the great hypoglossal nerve, by M. Buffet-Delmas.—On the ovary and the egg of *Gobius minutus*, by M. Frédéric Guitel.—Note on the magnetic perturbations of March 11–13, 1892, by M. Th. Moureaux.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

Books.—Note-book of Agricultural Facts and Figures, 4th edition: P. McConnell (Lockwood).—A Year-book of Science, 1891: edited by Prof. Bonney (Cassell).—Willing's British and Irish Press Guides, 1892 (Willing).—Sitzungsberichte der K.B. Gesellschaft der Wissenschaften, Math. Naturw. Classe, 1891 (Prag).—Abhandlungen der Mathematisch-Naturwissenschaftlichen Classe der K.B. Gesellschaft der Wissenschaften von den Jahren 1890-91. vii. Folge, 4 Band (Prag).—Health Springs of Germany and Austria, 2nd edition: F. O. Buckland (Allen).—The School Calendar, 1892 (Whittaker).—Silk Dyeing, Printing, and Finishing: G. H. Hurst (Bell).—Le Poil des Animaux et les Fourrures: Lacroix Danliard (Paris, Baillière).—Les Fleurs à Paris: P. L. de Vilmorin (Paris, Baillière).—Statistics of the Colony of Tasmania for the Year 1890 (Tasmania, Strutt).—Anatomie et Physiologie Comparées de la Pholade Dactyle: Dr. R. Dubois (Paris, Masson).

Pamphlets.—Neue Integrationsmethoden auf Grund der Potenzial—Logarithmal und Numeral-rechnung: Dr. J. Bergbohm (Stuttgart).—Neue Rechnungsmethoden der Höheren Mathematik, Dr. J. Bergbohm (Stuttgart). O Theorii Ploch: E. Weyr (V. Praze).—Jahresbericht der K.B. Gesellschaft der Wissenschaften für das Jahr 1891 (Prag).

Serials.—Beiträge zur Kenntniss der Orchideen von H. G. Reichenbach fil fortgesetzt durch F. Kränzlin; Dritter Band, Fünftes Heft (Leipzig, Brockhaus).—Proceedings of the American Philosophical Society, vol. xxix. No. 136 (Philadelphia).—Bulletin de L'Académie Imperiale des Sciences de St. Pétersbourg. Nouvelle Série, II. xxxiv. (St. Pétersbourg).—Bulletin of the New York Mathematical Society, vol. i. No. 6 (New York).

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